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Meteorological Operations at Cape Hatt in Support of the Baffin Island Oil Spill Project

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ABSTRACT. Climatological records for Pond Inlet and Arctic Bay indicate that the climate of the northern Baffin Island area lies between the cold, dry climate of the central Arctic and the slightly milder and moister climates of the western Beaufort Sea and the southeastern Baffin Island and Hudson Strait areas. A weather station was set up at Cape Hatt in late May 1980 to provide climatological data at the site of the Baffin Island Oil Spill Project. Daily precipitation and temperatures, hourly winds, rate of rainfall and hourly global solar radiation were measured. The station operated from late May to late June and from mid-July to the end of September in 1980 and from mid-July to early September in 1981. Temperature and precipitation data from the station were compared with those from Pond Inlet for the identical periods. Six outlying stations measured winds at representative locations in the area. Hour by hour comparisons were made of the winds at five shoreline stations with those at the camp station and those on a nearby mountain. These were used as one of the tools in forecasting winds for the oil releases.

The weather forecasting system utilized one meteorologist at the site using weather charts and briefings from the Atmospheric Environment Service Arctic Weather Centre at Edmonton. The forecasts provided met all requirements for timing and accuracy.

Key words: climatological, Baffin Island, weather station, precipitation, temperature, winds, radiation, forecasting

RÉSUMÉ. Les relevés climatologiques pour Pond Inlet et Arctic Bay indiquent que le climat de la région au nord de l'île Baffin se situe entre le climat froid et sec de la région arctique centrale et les climats légèrement plus doux et plus humides de l'ouest de la mer de Beaufort et des régions du sud-est de l'île Baffin et du détroit d'Hudson. Une station météorologique a été installée au cap Hatt fin mai 1980 pour fournir des données climatologiques au site du projet de déversement de pétrole à l'île Baffin. On a mesuré les précipitations et les températures quotidiennement, les vents et le rayonnement solaire global toutes les heures, ainsi que les taux de pluie. La station a fonctionné de fin mai à fin juin et de mi-juillet à fin septembre en 1980, et de mi-juillet à début septembre en 1981. On a comparé les données de température et de précipitation obtenues à cette station avec celles de Pond Inlet pour les mêmes périodes. Six stations périphériques ont mesuré les vents à six endroits représentatifs de cette région. On a comparé les vents mesurés aux mêmes heures à cinq stations côtières avec ceux de la station de base et ceux sur une montagne proche. On s'est servi de ces comparaisons comme d'un des outils pour prévoir les vents lors des déversements de pétrole. Un météorologue est resté sur place pour s'occuper du système de prévision du temps en se servant de cartes météorologiques et de bulletins du centre météorologique arctique du Service de l'environnement atmosphérique à Edmonton. Les prévisions émises ont satisfait à toutes les exigences quant à l'exactitude de l'heure et du contenu.

Mots clés: climatologique, île Baffin, station météorologique, précipitation, température, vents, rayonnement, prévisions

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INTRODUCTION

This paper is part of the reported results of the Baffin Island Oil Spill (BIOS) Project. The project monitored experimental releases of crude oil in the arctic nearshore. Measurements were made of the fate and effects of dispersed oil and of an oil slick stranded on the shoreline and left to natural cleaning processes. The effectiveness of shoreline cleanup techniques under arctic summer conditions was also evaluated. The BIOS Project rationale, design and an overall summary of results are presented in Sergy and Blackall (1987).

The project was designed to be carried out on a small, but life-size, scale under natural arctic summer conditions. It was anticipated that meteorology would significantly affect the BIOS Project in both the execution of the experiments and the assessment of results. In particular, the local wind at the experimental site was expected to be one of the main factors that would govern the deposition of the surface oil slick on the beach. It would also affect nearshore currents, which in turn were expected to determine the distribution of the subsurface oil and dispersant mixture. Temperatures and solar radiation affect energy exchanges. These would have to be examined in assessing results of some experiments for their effects on biological activity and on the weathering of beached oil.

Finally, it had to be determined in advance that there was a high probability that satisfactory sets of meteorological conditions would occur, preferably more than once, for each experiment during the brief period when the experiments could be carried out. An assessment was made to confirm that the chosen site was representative from a climatic point of view of a large proportion of shorelines in the Canadian Arctic. Maxwell (1982) provides a complete description of the climate of the Canadian arctic islands and adjacent waters. Findlay and Treidl (1977) and internal Atmospheric Environment Service of Environment Canada (AES) publications were used in the original assessment.

OBJECTIVES

The site for the project had to be carefully selected to ensure that the results would be applicable to a significant portion of arctic coastlines. The first objective of the meteorological component was to determine that the chosen area would meet these requirements with respect to weather and climate.

The second objective was to provide meteorological data for those aspects of weather and climate that would have direct and significant effects on the BIOS experiments and on the evaluation of the results. The oceanographers, in particular, used the 1980 wind data in developing models of ocean currents, waves and tides.

The third objective, which became the major objective in the 1981 field season, was to provide meteorological consultation and accurate forecasts of local winds over the experimental bays. Forecasts of general weather conditions affecting the project were also to be provided. The forecasts were to cover periods long enough to encompass the time required for decision making, marshalling resources, the experiment itself and a

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follow-up period for cleanup. These services were to be available for each of the two main spills and for the dye tests and any other dry runs of the experiments. They would be required throughout the spill period (early August until both spills had been completed).

METHODS

Site Evaluation

Site evaluation in terms of climate consisted of a literature review and comparison of standard climatological data as published by AES. Pond Inlet data were compared with other stations in the North Baffin Island area and other coastal stations across the Canadian Arctic from northern Quebec to the Beaufort Sea. The climate evaluation was later refined by comparing Cape Hatt temperatures and precipitation for periods from late May to early September 1980 with those from Pond Inlet for the same periods. The literature and the data indicate that winds from the observing sites are strongly site dependent (Parker and Alexander, 1983). It was assumed initially that local wind conditions would not preclude the likelihood of successful completion of the experiments. Low-level (2 m) wind measurements were taken during the summer of 1980 at five locations on the shorelines near the candidate bays on both sides of Cape Hatt in order to determine to what extent that assumption was valid. Details of those measurements are discussed below.

Measurements

The main weather station at the camp and the outlying wind stations were installed near the end of May 1980. All of the sensors were of standard types for AES stations. An instrument area was set up at the northwest edge of the camp just above the shore of an adjacent freshwater pond (see Fig. 1). Maximum and minimum thermometers and a motor driven psychrometer with wet- and dry-bulb thermometers were installed in a Stevenson screen erected to AES standards. An AES Type 45B anemometer was mounted on a standard 10-m mast near the centre of the instrument area. The tipping bucket automatic rain gauge, an AES Type B standard rain gauge and a newly calibrated Kip and Zonen model CM-5 pyranometer were also mounted in the instrument area. Ceiling balloon equipment was provided for cloud height measurements as an aid to local aircraft movements when required. Climatological parameters recorded at the main station are listed in Table 1. Other parameters were added to provide weather reports for transmission to the Polar Continental Shelf Program (PCSP) network. Observations were taken twice daily, at 0800 and 2000 EDT during the periods when the camp was open in 1980 and 1981.

Six outlying wind stations were operated for various periods during the 1980 and 1981 field seasons using AES Type 45B anemometers (see Fig. 1).

At station Met 2 an anemometer was mounted on a standard 10 m mast erected on the brow of the mountain to the north of the camp at an elevation of approximately 375 m. The purpose of this station was to obtain the most representative possible estimate of the undisturbed wind in the area.

The other five outlying stations were installed on the shorelines on each side of the project site. The locations were selected to be representative of the bays to be considered as possible sites for the nearshore spills. These five anemometers were mounted on 2 m pipe masts located as close to the high-water mark as

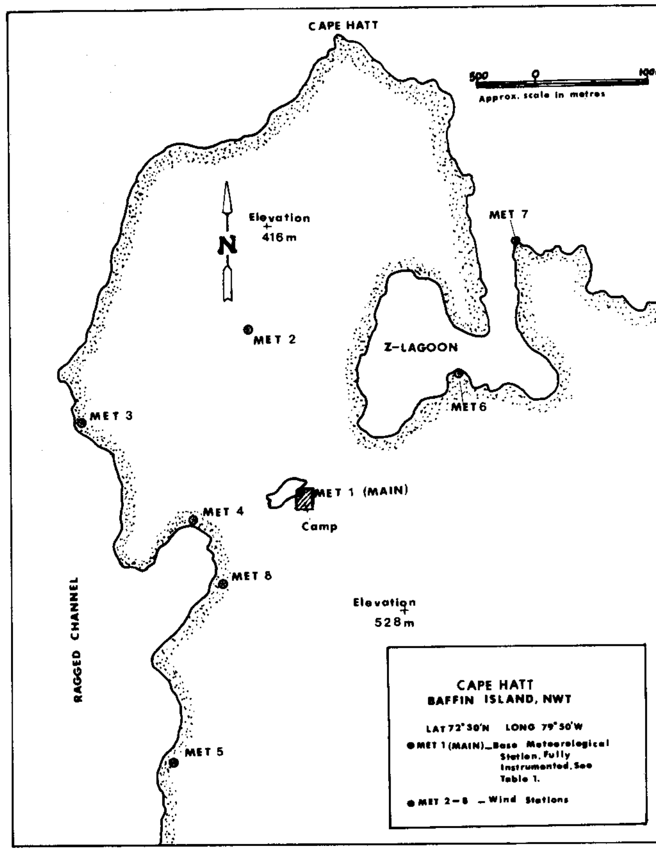

FIG. 1. Meteorological station locations, Cape Hatt.

possible. Details of the meteorological stations are shown in Table 1.

Observations of maximum and minimum temperatures passed the normal accuracy checks until late August 1981, when some readings began to show up that were contradicted by the air temperature at the previous observation. Temperature data for September 1981 were discarded on this account.

Forecast Operations

The forecasting operation was based on the use of routine analyses and surface prognostic charts received at Cape Hatt from the Arctic Weather Centre at Edmonton via long distance telephone (satellite). The maps were supplemented by a verbal telephone briefing from the duty forecaster for confidence factors and longer range outlooks. In addition, supplementary weather reports were obtained from the Resolute Bay Weather Office, from which an intermediate surface weather map (1200 GMT) was plotted and analyzed at the camp. Briefings could also be obtained from the Resolute Bay office if communications with Edmonton failed. Upper winds were determined by following ceiling balloons with a theodolite, using a modification of the standard pilot balloon method and a programmable hand calculator. These observations provided information on winds in the free atmosphere (i.e., above the friction layer) in the area. Wilson (1973, 1974) provided the theoretical basis for the estimation of local wind variations from the undisturbed wind field.

TABLE 1. Meteorological stations at the BIOS Project site

Station	Anemometer Type	Mast ht	Recorder	Other instruments	Parameter measured	Units	Periods of operation
Met 1 (Main)	MSC 45B	10 m	E-A pulse		hourly wind	$km \cdot h^{-1}$	1980 29 May-2 June, 9-26 June, 21 July-25 Sept 1981 19 July-5 Aug, 9 Aug-8 Sept
				drybulb thermometer	air temp	°C	1980 29 May-25 June, 23 July-31 Aug 1981 20 July-11 Sept
				wetbulb thermometer	wetbulb temp	°C	1980 29 May-25 June, 23 July-31 Aug 1981 20 July-11 Sept
				maximum thermometer	maximum daily temp	°C	1980 28 May-25 June, 23 July-14 Sept 1981 20 July-11 Sept
				minimum thermometer	minimum daily temp	°C	1980 28 May-25 June, 23 July-12 Sept 1981 20 July-12 Sept
				AES Type B rain gauge	24 h rainfall	mm	1980 28 May-25 June, 23 July-14 Sept 1981 20 July-12 Sept
				MSC TBRG	rate of rainfall	$mm \cdot h^{-1}$	1980 29 May-25 June, 23 July-13 Sept 1981 20 July-5 Aug, 9 Aug-8 Sept
				Kipp & Zonen pyrheliometer	global solar radiation	$MJ \cdot m^{-2}$	1980 29 May-25 June, 20 July-30 Sept 1981 not abstracted
Met 2	MSC 45B	10 m	E-A pulse		hourly wind	$km \cdot h^{-1}$	1980 25 May-4 July, 19 July-17 Aug, 2-30 Sept 1981 19 July-25 Aug
Met 3	MSC 45B	2 m	E-A pulse		hourly wind	$km \cdot h^{-1}$	1980 24 May-25 June, 19 July-24 Sept 1981 closed
Met 4	MSC 45B	2 m	MSC anemograph		hourly wind	$km \cdot h^{-1}$	1980 24 May-25 June, 19 July-28 Sept 1981 9-22 Aug
Met 5	MSC 45B	2 m	E-A pulse		hourly wind	$km \cdot h^{-1}$	1980 23 May-25 June, 3-18 Aug 3 Aug-30 Sept 1981 9 Aug-4 Sept
Met 6	MSC 45B	2 m	MSC anemograph		hourly wind	$km \cdot h^{-1}$	1980 25 May-24 June, 19 July-25 Aug 4-5 Sept 1981 closed
Met 7	MSC 45B	2 m	E-A pulse		hourly wind	$km \cdot h^{-1}$	1980 26 May-25 June, 8-30 Sept 1981 closed
Met 8	MSC 45B	2 m	E-A pulse		hourly wind	$km \cdot h^{-1}$	1981 only 15-19 Aug, 23 Aug-2 Sept, relocated from Met 7

MSC — Meteorological Service of Canada, a previous designator for AES.
E-A pulse — Esterline Angus multichannel pulse recorder.
MSC TBRG — MSC tipping bucket rain gauge.

RESULTS AND CONCLUSIONS

Climate and Representativeness of Cape Hatt

The overall similarities in temperature, precipitation and global solar radiation between the various arctic coastal stations from Tuktoyaktuk to Frobisher Bay relative to a coastal station in the temperate zone (St. Johns) are evident in Tables 2 and 3, although there are also some significant differences. Precipitation at Frobisher Bay was two or more times greater than at Pond Inlet or any other station in the central or western Arctic. Temperatures at Frobisher Bay averaged just slightly higher. Nevertheless, the selection of Cape Hatt appears to be a reasonable compromise insofar as climate is concerned. These data are abstracted from the series *Canadian Climatic Normals* (Environment Canada, 1982).

Mean maximum and minimum temperatures for Cape Hatt and Pond Inlet for the portions of months when the Cape Hatt station operated are presented in Table 4. Root mean squares of daily differences between the two stations are included in the table to indicate the dispersion in daily values. These data indicate a strong similarity between temperatures at Cape Hatt and Pond Inlet.

Precipitation is often strongly variable in time and space, so the short periods of record available for Cape Hatt can be used only for a rough comparison with Pond Inlet. The comparison is further complicated because the period 1-25 June 1980 was extremely dry, with no measurable precipitation at Cape Hatt and only 0.2 mm at Pond Inlet, while August in both 1980 and 1981 was marked at both stations by two to three times Pond Inlet's normal precipitation for the month. Total precipitation for the periods when observations are available from Cape Hatt are presented in Table 5. For purposes of comparison, it was considered useful to compare dry and wet days at Pond Inlet and Cape Hatt on a day-to-day basis (Table 6).

TABLE 2. Climatological data for Pond Inlet and selected arctic stations

Monthly mean of[1,2,3]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
	for Pond Inlet												
Daily max temp	−26.4	−28.0	−26.9	−17.4	−4.8	3.5	7.9	7.8	1.7	−7.4	−17.8	−24.4	−11.0
Daily min temp	−35.1	−37.1	−34.9	−25.0	−13.6	−1.8	1.2	1.7	−3.8	−13.1	−25.0	−32.1	−18.2
Daily mean temp	−30.7	−32.7	−31.1	−21.7	−9.3	0.9	4.6	4.9	−1.0	−10.2	−21.5	−28.4	−14.7
σ Daily mean	4.2	2.6	3.4	4.0	2.6	1.3	0.6	0.8	1.3	2.6	3.1	2.5	0.1
Total precip	*5.9	M	*9.7	*2.7	*13.7	*9.4	26.7	23.9	*32.2	*16.5	*11.0	*7.2	
σ Total precip	6.2	8.9	17.5	1.7	14.8	7.4	16.7	9.7	12.3	23.3	6.9	8.6	
	for Arctic Bay												
Daily mean temp	−29.7	−31.2	−28.7	−20.3	−8.0	1.5	5.6	4.6	−1.7	−11.4	−22.4	−27.4	−14.1
σ Daily mean temp	2.7	3.2	4.1	3.1	2.7	1.5	0.8	1.0	1.3	2.8	2.8	3.3	1.0
Total precip	*6.0	*3.2	*3.4	*4.3	*5.0	7.3	18.1	22.1	*22.5	*15.9	*6.3	*4.2	118.3
σ Total precip	3.0	2.7	3.2	5.0	4.6	10.3	13.0	16.3	12.8	10.3	4.6	4.1	34.4
	for Frobisher Bay												
Daily mean temp	−25.6	−25.9	−22.7	−14.3	−3.2	3.4	7.6	6.9	2.4	−5.0	−13.0	−21.8	−9.3
σ Daily mean	4.5	4.7	4.5	3.1	2.2	1.5	1.2	0.9	1.1	2.7	3.1	4.0	1.2
Total precip	*26.1	*23.3	*23.3	*26.4	*25.3	39.4	63.3	58.9	46.0	*44.1	*34.4	*22.1	432.6
σ Total precip	20.1	22.6	17.9	21.4	13.8	18.7	33.3	25.4	24.6	22.8	15.3	16.4	99.9
	for Cambridge Bay												
Daily mean temp	−33.6	−34.4	−31.3	−21.9	−9.4	1.5	7.9	6.5	−0.7	−11.7	−23.8	−30.0	−15.1
σ Daily mean	2.5	3.1	2.4	3.1	2.7	2.4	1.3	1.7	1.9	3.3	2.2	3.1	1.0
Total precip	*4.8	*4.0	*4.7	*7.2	*9.5	13.2	19.7	28.0	17.3	*14.8	*7.7	*5.4	136.3
σ Total precip	3.9	3.2	3.6	5.5	6.1	12.3	14.1	17.8	7.0	8.8	4.4	4.1	27.0
	for Resolute A												
Daily mean temp	−32.1	−33.2	−31.4	−23.1	−10.9	−0.6	4.1	2.4	−5.1	−15.1	−24.5	−29.3	−16.6
σ Daily mean	3.1	3.4	3.1	2.8	2.4	2.0	1.3	1.3	1.5	2.8	2.8	2.4	0.9
Total precip	*3.3	*3.0	*3.0	*5.9	*8.1	*12.1	22.5	31.1	*18.0	*13.8	*5.7	*4.9	131.4
σ Total precip	2.1	2.2	1.8	3.9	4.7	9.3	15.5	16.1	11.0	6.9	4.3	3.3	28.6
	for Tuktoyaktuk												
Daily mean temp	−28.4	−29.1	−26.5	−17.2	−4.7	5.1	10.6	9.0	2.6	−7.7	−19.7	−25.2	−10.9
σ Daily mean	3.4	3.5	3.0	3.1	1.9	1.7	1.6	2.0	2.0	2.7	3.3	3.3	1.2
Total precip	*5.3	*5.4	*4.4	*7.1	*5.9	12.9	19.9	27.8	14.9	*17.6	*8.9	*7.4	137.6
σ Total precip	5.4	5.2	4.8	6.5	6.9	11.1	13.7	18.3	8.1	10.3	7.3	6.0	36.7
	for St. John's, Newfoundland												
Daily mean temp	−3.5	−4.0	−1.7	2.0	6.3	11.6	16.1	16.0	12.2	7.6	3.8	−1.0	5.5
σ Daily mean	2.0	3.1	2.2	1.3	1.5	2.0	1.8	1.5	0.7	1.0	1.6	2.4	0.7
Total precip	164.8	141.4	131.2	108.5	95.7	70.5	60.6	105.7	101.0	135.9	146.9	158.3	1420.5
σ Total precip	53.9	64.6	50.9	52.4	34.8	34.0	36.7	73.9	38.2	39.1	50.3	40.3	194.0

[1]Temperatures in °C. Daily mean temperature is the median of the maximum and minimum temperatures for the day. The monthly mean of daily mean temperature is the mean of all daily values recorded in that month from 1951 to 1980 inclusive.
[2]Precipitation in mm. The total precipitation values are monthly and annual totals of the daily amounts that have been averaged over the period 1951-80 inclusive for all the months for which records are available. Total precipitation is rainfall plus the water equivalent of snowfall and all other forms of frozen precipitation.
[3]σ Daily mean (total precip) — The standard deviation of the daily mean temperature (total precipitation).
*Over half of the total precipitation is accounted for by snowfall.

TABLE 3. Global solar radiation and sunshine data for selected arctic stations

Monthly mean of[1]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
	for Frobisher Bay												
RF1 (radiation)	0.84	3.52	9.19	17.61	21.20	19.74	16.42	12.81	7.42	3.31	1.14	0.39	
Hours of sunshine	35.2	96.3	177.4	235.3	199.9	175.2	202.1	161.2	82.4	57.8	45.6	19.6	1488.0
	for Resolute Bay												
RF1 (radiation)	0.0	0.63	5.24	14.72	23.05	24.91	18.69	11.03	5.22	1.28	0.07	0.0	
Hours of sunshine	0.0	17.7	145.9	276.4	292.3	255.8	274.4	159.4	59.1	23.7	0.4	0.0	1505.1
	for Inuvik UA												
RF1 (radiation)	0.19	1.88	7.82	15.19	19.65	22.41	20.02	13.25	6.40	2.20	0.41	0.03	
Hours of sunshine	7.3	65.2	174.1	248.7	295.0	375.1	339.8	216.2	109.4	50.2	17.8	0.0	1898.9
	for Cambridge Bay												
RF1 (radiation)	0.19	1.82	7.57	16.03	21.76	23.16	18.54	11.97	6.20	2.85	0.39	0.0	
Hours of sunshine	1.1	51.7	184.4	251.5	258.2	267.8	304.6	175.9	82.6	58.2	9.5	0.0	1599.0
	for Goose A												
RF1 (radiation)	3.49	6.92	11.53	15.75	17.80	18.50	17.63	14.40	10.09	5.90	3.21	2.53	
Hours of sunshine	88.3	116.9	129.3	139.8	176.3	187.3	196.4	176.4	121.3	93.6	66.0	73.3	1564.9

[1]Global Solar Radiation (RF1) in megajoules per square metre ($MJ \cdot m^{-2}$) — The RF1 data in the table are the mean daily totals averaged over the available period of record for the station and over the month or year. Hours of (bright) sunshine are the mean monthly or annual totals of the number of hours of bright sunshine recorded daily, averaged over the available period of records 1951-80.

TABLE 4. Comparison of mean daily temperatures at Cape Hatt and Pond Inlet by month or partial month[1]

	1980				1981	
Period	June	July	Aug	Sept	July	Aug
Maximum temperatures (°C)						
No. of days obs[2]	25	9	31	13	11	29
Mean max for period at CH[3]	2.67	6.34	7.43	5.64	6.75	6.55
Mean max for period at PI[3]	2.60	7.08	7.90	5.19	6.95	6.57
rms of daily difference[4]	1.50	2.45	2.03	1.43	1.32	1.59
Minimum temperatures (°C)						
No. of days obs[2]	25	9	31	12	12	29
Mean min for period at CH[3]	−3.83	1.01	2.53	0.64	1.49	2.52
Mean min for period at PI[3]	−3.59	0.97	2.35	−0.14	1.48	1.71
rms of daily difference[4]	1.66	0.44	0.06	1.23	0.76	1.35

[1]Only those days when maximum (minimum) temperatures were available from both Pond Inlet and Cape Hatt were used in computing the mean for each period.
[2]No. of days obs — The number of daily values used in computing the means for both stations for the period.
[3]Mean max (min) period at CH (PI) — The mean maximum (minimum) temperature at Cape Hatt (Pond Inlet) for the period.
[4]rms of daily difference — the root mean square of the differences between the maximum (minimum) temperatures at Cape Hatt and Pond Inlet for the days used in computing the means.

TABLE 5. Comparison of total precipitation at Cape Hatt and Pond Inlet for observation periods of months or partial months[1]

	1980				1981		
Period	June	July	Aug	Sept	July	Aug	Sept
No. of days obs[2]	25	9	31	12	12	31	11
Total precip CH mm	0.0	13.0	54.7	12.9	19.6	55.3	20.5
Total precip PI mm	0.2	14.4	47.6	6.4	8.0	73.0	16.0
Days with precip CH[3]	0	6	11	3	6	21	6

[1]Only those days in the observation period when data were available from both Cape Hatt and Pond Inlet were used in calculating the total precipitation (mm) at each station for the period.
[2]No. of days obs — the number of days in the observation period used in calculating total precipitation.
[3]Days with precip CH — the number of days in the period when measureable precipitation was recorded at Cape Hatt.

TABLE 6. Comparison of precipitation[1] days at Cape Hatt and Pond Inlet

		Days with		
Year	No. of obs[2]	nil or tr both stations	precip both stations	precip only one station
1980	78	53	18	7
1981	54	15	23	16

[1]Precipitation — measureable precipitation, i.e., 0.2 mm or greater.
[2]No. of obs — only those days when precipitation data were available from both stations were used in the tabulation.

TABLE 7. Comparison of mean daily global solar radiation at Cape Hatt, Frobisher Bay and Resolute Bay by month or partial month

	Period 1980			
	June	July	Aug	Sept
No. of days obs[1]	25	12	31	29
Mean daily global solar radiation (MJ·m^{-2})				
Cape Hatt	29.53	15.68	11.60	5.61
Frobisher Bay	17.24	18.41	14.36	7.65
Resolute Bay	24.74	14.69	10.65	4.88

[1]No. of days obs — the number of days in the period when data for Cape Hatt were available. The means quoted for Cape Hatt are the mean of the daily values for those days. The data for Frobisher Bay and Resolute Bay were taken from the AES monthly publication of radiation data, adjusted or recalculated as required to match them to the periods of record for Cape Hatt.

Mean daily global solar radiation at Cape Hatt for the months or partial months of June-September 1980 are compared in Table 7 with those for Resolute Bay and Frobisher Bay for the same period. Radiation at Cape Hatt for June was well above the normal for any arctic station, but this departure should be viewed in the context of a (partial) month in which precipitation was nil, suggesting that cloud cover was also far below normal. July and August radiation data fit well with both the 1980 data and the normals for Resolute Bay. By September the latitudinal variation of solar radiation normals become more pronounced. The Cape Hatt data fit the regional trend derived from Resolute Bay and Frobisher Bay data for the same month.

Winds at the Experimental Sites

The fetch across Eclipse Sound is sufficient to allow winds off the sound to approach the gradient wind at the exposed shores of Cape Hatt. Winds over the experimental bays in Z-Lagoon and along Ragged Channel were generally decreased and altered by the local topography. It was essential to the project that these differences be known both in general terms for overall planning and in specific detail for daily go or no-go decision making. Winds were found to be a driving mechanism for the currents in Ragged Channel (Buckley *et al.*, 1987), so that they affected the timing of the dispersed oil release as well as the surface oil release.

Analysis of the 1980 wind data supported the earlier assumption that suitable episodes of wind speed and direction for one or both of the nearshore oil release experiments would occur at most of the candidate bays, including the two bays that were selected.

Wind direction distributions using available data from 9 August 1981 to station closing are shown in Figure 2, with the 1980 distributions displayed alongside for comparison. Directions were estimated for station 1 (Main Camp) for the period 9-18 August 1981. Crossbars on the east, southeast, southwest and west direction vectors represent minimum and maximum possible percentages of winds from those directions. Overall patterns show good agreement, considering the size and representativeness of the samples, with minor variations. The greater frequency of southwesterly winds at stations Met 4 and Met 8 in 1981 worked to the advantage of the project. A marked decrease in the frequency of east winds at the north mountain station is readily explained by the absence of low pressure systems to the south and southwest of Cape Hatt in 1981, whereas there were several in 1980. The overall circulation pattern is discussed later.

heavy precipitation for the month of August and the infrequent occurrence of east winds at the mountaintop station in 1981. There was also an increase in the frequency of southwest winds at several of the sites, especially in the Bay 11-12 complex.

These anomalies may be partially explained by reference to Figure 3, showing the tracks of low pressure centres 8-31 August 1981. Most of the tracks fall farther north than the typical (secondary) storm track for August (Fig. 4; McKay *et al.*, 1970). The more northerly tracks suggest that warmer air aloft, with its greater moisture-carrying capacity, extended to the northern Baffin Island area for much of the month, producing heavier rains. The more northerly track also resulted in the lack of low pressure centres to the south and southwest of Cape Hatt and, consequently, fewer winds from the east quadrant and more from the west. This increased the number of favourable opportunities for the surface oil release at Bay 11.

The Surface Oil Release

The surface oil release was planned to take place over the

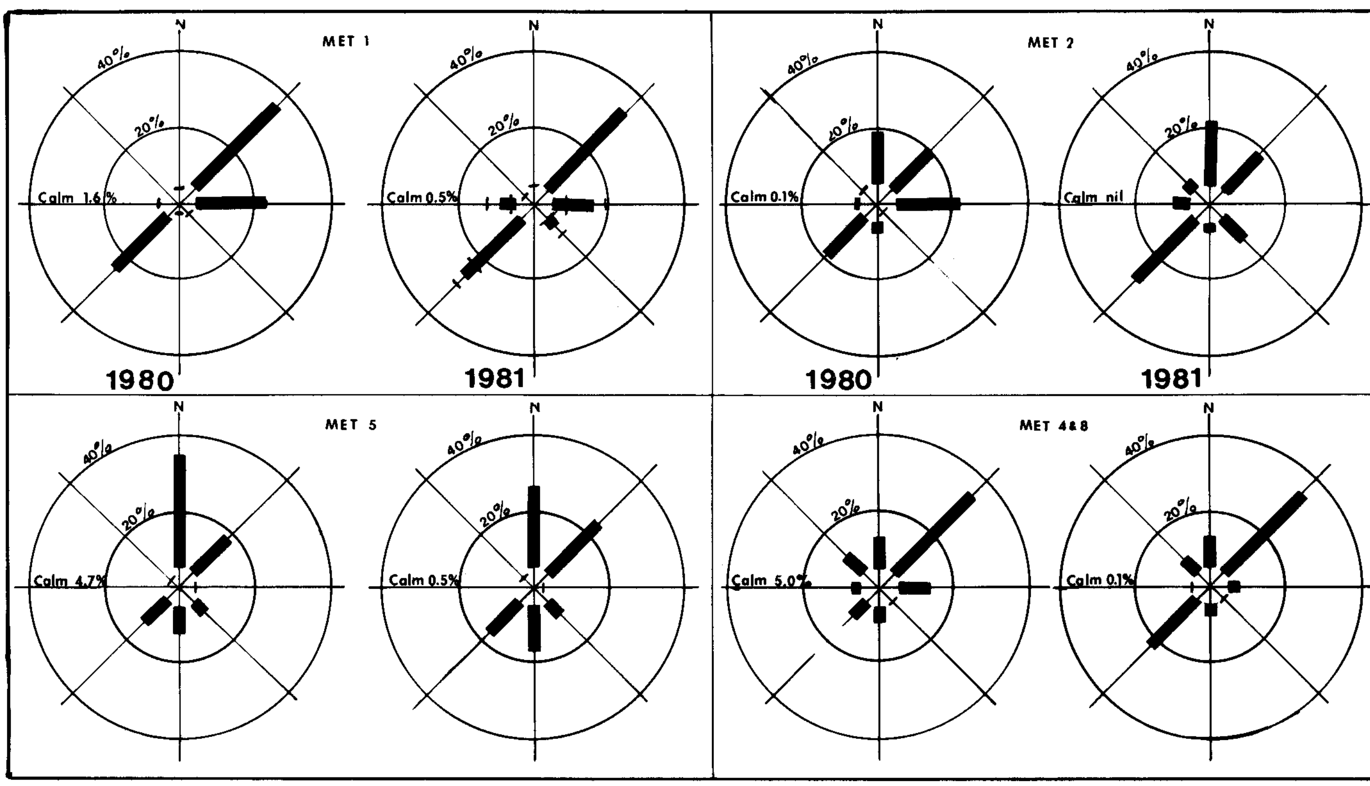

FIG. 2. Wind direction frequency distributions, selected stations at Cape Hatt. Frequencies of less than 2.5% are not plotted. Frequencies between 2.5% and 5% are marked by a single line across the direction vector within the open space at the centre of each diagram.

Wind directions at station Met 8 showed good agreement with those at station Met 4 during the brief period when both stations were recording with good reliability. Only one hour differed by more than one compass point when the wind speed was 16 km·h^{-1} or greater. In periods of light winds the variability was greater but was not a serious factor in the experiment.

Weather Anomalies in 1981

There were two anomalies in the observed weather at Cape Hatt during the operational period in 1981. These were the

duration of a single falling tide coincident with a persistent onshore component of the wind. Wind speeds of 15-25 km·h^{-1} would ensure the movement of the oil slick onshore without creating serious difficulty in containing and recovering the residual oil.

During the period 15 August-3 September these conditions were fully satisfied overnight on 18-19 August and on the next falling tide in the afternoon of 19 August. They were also satisfied across midday on 30 and 31 August and on 2 September. The oil release was carried out on the best of these opportunities during the daytime falling tide of 19 August.

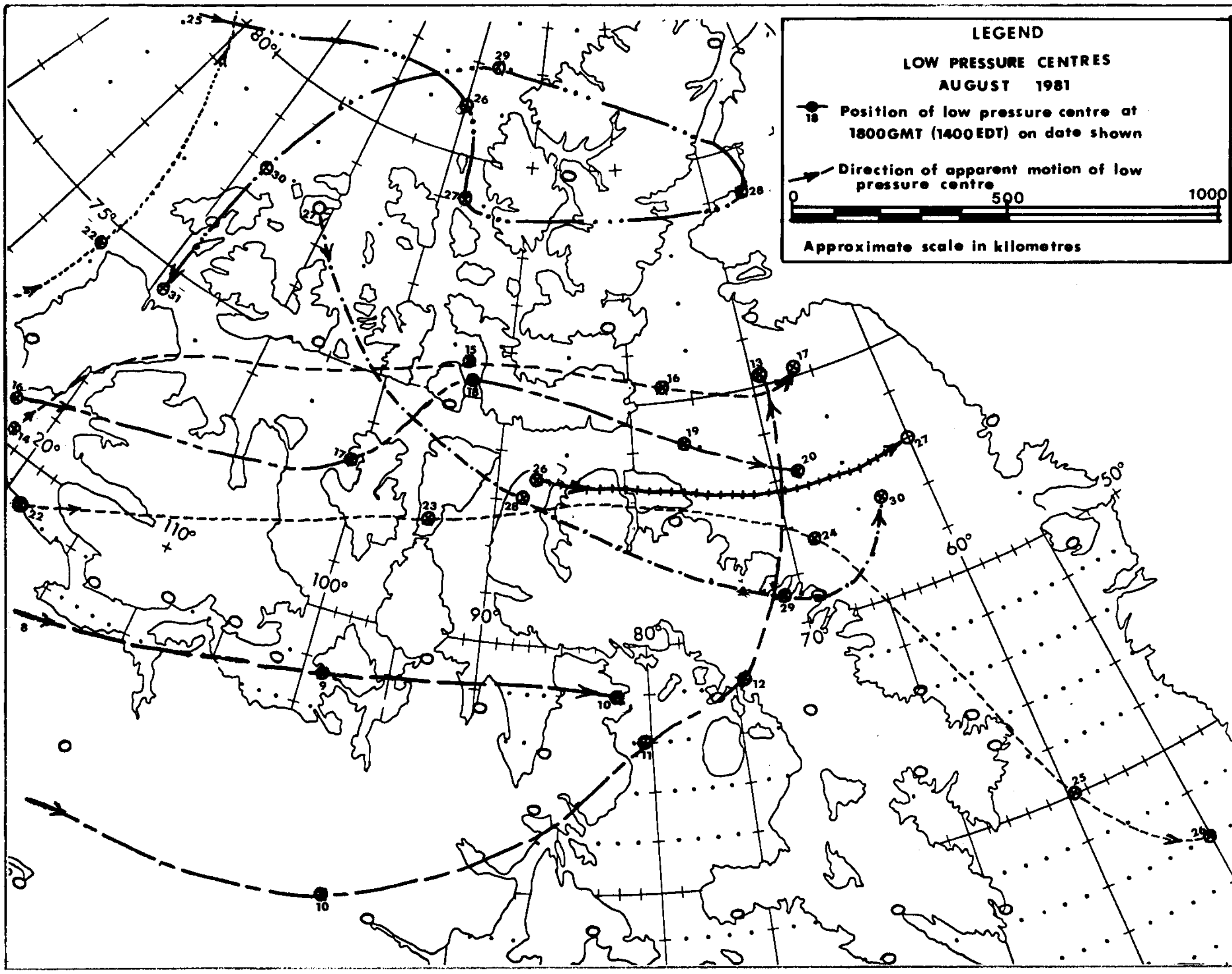

FIG. 3. Storm tracks, 9-13 August 1981. Tracks beginning or ending at a low-pressure centre position indicate the formation of a new low-pressure centre or the disappearance of a decaying system.

Winds at Bays 11 and 12 during the oil release ranged from 16 to 21 km·h^{-1}, dropping to 10 km·h^{-1} by 1800 EDT and to 5 km·h^{-1} at midnight. The maximum temperature during the day was 5.3°C and the minimum 3.0°C. The previous day 4.6 mm of rain had fallen, but the weather on 19 August was fair, with no precipitation. The oil slick was blown at an acute angle to the beach, permitting coverage of the entire test area with a small movement of the spill apparatus located near the south end of the beach. The favourable test conditions had been forecast more than 24 h in advance, allowing the relocation of pumps and other equipment from the dispersed oil release site.

Following the spill, wind speeds remained light on 20 August until 1600 EDT, rising briefly to northeast 21 km·h^{-1} at 1900 EDT, then dropping back to less than 5 km·h^{-1} by midnight. Temperatures ranged from a minimum of 2.0 to a maximum of 5.0°C. Winds remained under 15 km·h^{-1} through 21 and 22 August, increasing slightly to a maximum of 18 km·h^{-1} from the southwest at noon on 23 August and ranging from 6 to 16 km·h^{-1} for the rest of the day. The weather was dry from 20 August 0800 EDT until near midnight 23 August. Heavy rain (compared to previous records for Pond Inlet) occurred on 24 and 25 August, totalling 14.6 mm in 48 h. Temperatures increased daily from 20 to 22 August to a maximum on 22 August of 10.7°C.

These weather conditions were near optimum for the oil release and for the tasks of data collection and cleanup following the spill.

The Dispersed Oil Release

Timing of the dispersed oil release was more dependent on ocean currents than on winds. Wind forecasts and observations were important insofar as the wind was one of the driving mechanisms for the currents. Dye tests of the oil dispersal system on 16 August (Dickens *et al.*, 1987) showed that northward-moving currents in the nearshore at Bay 9 were not as dependable as earlier data had implied, so the experiment was revised. The dispersal pipe was moved toward the south end of the test area. Wind requirements were reversed. However, further dye tests with this setup and southwesterly winds also produced unsatisfying results. Then sustained northerly winds occurred from 24 August 1200 EDT until 26 August 0300 EDT, averaging near 30 km·h^{-1} through the morning of 25 August. This wind episode showed that a falling tide with moderate to strong northerly winds beginning several hours before the onset of that tide and continuing through it would produce a rotary circulation (gyre) that would ultimately produce the desired distribution of oil and dispersant in Bay 9 (Buckley *et al.*,

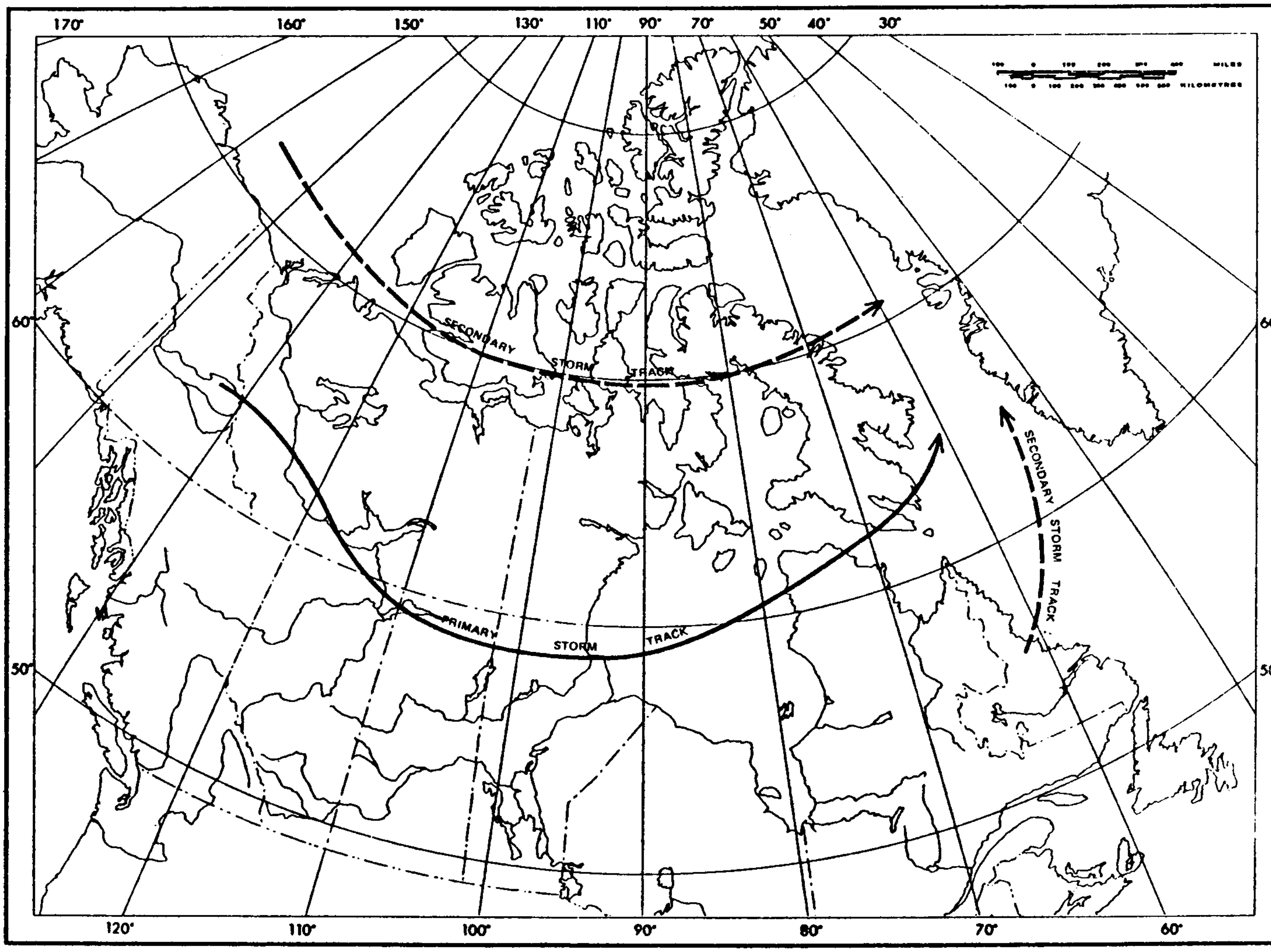

FIG. 4. Typical storm tracks, August (from McKay *et al.*, 1970). A large dot added to the original figure shows the location of Cape Hatt.

1987). Wind requirements were reversed again, from southwesterly to northerly. The on-site forecaster was able to react immediately to these changing requirements.

A second episode of northerly winds began near midnight of 26 August and continued for 24 h. The dispersed oil release took place on 27 August, with the second satisfactory wind episode. Those winds were correctly forecast more than 24 h in advance. The winds at station Met 5 were light to moderate southwesterly in the afternoon and evening of 26 August but shifted to the north at 32 km·h^{-1} at 2300 EDT that evening. They decreased gradually to 16 km·h^{-1} by 0900 EDT. Through the daylight hours of 27 August the winds remained northerly, with speeds of 16-22 km·h^{-1}, dropping to 12 km·h^{-1} at 1600 EDT. These winds were close to the optimum in direction, speed and duration as prescribed by the oceanographers. There were no other fully satisfactory wind situations for the dispersed oil release up to 3 September, when the anemometers were removed.

The weather on the oil release day was cool and dull with a maximum temperature of 0.1 and a minimum of −1.0°C. There was just a trace of snow in very light flurries. The weather remained much the same for the next four days, with a trace of snow on 28 August and 2.0 mm on 29 August. No measurable precipitation fell on the following two days. Temperatures changed very little during this period, reaching a minimum for the period of −2.5°C early in the morning of 31 August, then rising to the maximum for the five-day period, +2.5°C, later the same day. Wind speeds were light on the two days following the oil release, except briefly near 20 km·h^{-1} near midnight of 28 August and increasing again late in the evening of 29 August to near 30 km·h^{-1}. These weather and wind conditions were fully satisfactory for the tasks of gathering data and recovering and dismantling equipment following the dispersed oil release.

DISCUSSION

Representativeness of Wind Stations

Data from the BIOS Project clearly illustrate the extensive variation of surface winds over a small area due to local and regional topography. They also show that wind data from existing meteorological stations (specifically Pond Inlet in this case) are often not representative of any sort of mean regional wind. The stations are often located at existing settlements. In the Arctic, protection from strong winds must be one of the important considerations in selecting a settlement site. The high frequency of calms at Pond Inlet is an indication of that selection process in action. It is also probably indicative of other distortions in the wind pattern at that station. In this context, it was unfortunate that temporary closure of the meteorological station at Nanisivik coincided almost exactly with the BIOS Project's operating window. Nanisivik winds appear to be more representative of the general circulation in the northern Baffin Island area due to the location of the station at a very exposed site on a plateau at an elevation of 639 m.

Typicalness of the Climate and Weather at Cape Hatt

Mean temperatures and precipitation at Pond Inlet have been shown to be close to a median of those of the various coastal regions of the Canadian Arctic. Temperatures and precipitation at Cape Hatt for seven months or partial months during the summers of 1980 and 1981 were similar to those at Pond Inlet for the identical periods. The samples are too small to be definitive but they do lend some support to the assumption that differences in the climates of Cape Hatt and Pond Inlet would be insignificant in terms of the objectives of the project.

Precipitation during August 1981 was anomalous in comparison with previous records from Pond Inlet. Both Cape Hatt and Pond Inlet received close to three times the normal precipitation for August at Pond Inlet.

Recommendations for Forecast Services

The forecast operation performed satisfactorily and very nearly as planned. Dependence on the Arctic Weather Centre for analysis and prognosis support appears to be practical for this scale of operation. The use of telecopiers for transmission of weather charts was satisfactory. Newer technologies using personal computers connected directly to the Weather Centre computer through modems and a direct telephone link would make the system simpler and more reliable. The radio link from the satellite telephone receiver at Pond Inlet to the camp at Cape Hatt caused the loss of a few charts and some difficulty in voice transmissions. Nevertheless very few charts were missed. It is strongly recommended that a satellite antenna be made available on-site in the event of emergencies in the Arctic and/or for future projects such as BIOS. An on-site meteorologist with field experience or a highly qualified meteorological technician can provide quick reaction to changing requirements in the field.

Data accessibility from the remote wind stations would have been improved if a low-cost data logger with interface to the type 45B anemometer had been available off the shelf. Proven wind sensors of newer design with digital recording systems are now available. The wind data set from the 1980 season might be useful in testing topographic wind models.

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